

The magnetic field application for the gas discharge plasma control in processes of surface coating and modification

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Abstract. In this paper the method of magnetic field application to control the gas discharge plasma effect on the various surfaces in processes of surface coating and modification is considered. The magnetic field directed perpendicular to the direction of electric current in the gas discharge plasma channel is capable to reject this plasma channel due to action of Lorentz force on the moving electrically charged particles [1,2]. The three-dimensional spatial structure of magnetic field is created by system of necessary quantity of the magnets located perpendicular to the direction of course of electric current in the gas-discharge plasma channel. The formation of necessary spatial distribution of magnetic field makes possible to obtain a required distribution of plasma parameters near the processed surfaces. This way of the plasma channel parameters spatial distribution management is the most suitable for application in processes of plasma impact on a surface of irregular shape and in cases when the selective impact of plasma on a part of a surface of a product is required. It is necessary to apply automated computer management of the process parameters [3] to the most effective plasma impact.

1. Low-temperature plasma of gas discharges has been widely applied for a long time in various technological processes effecting the surface of materials: cleaning, modification, coating, plasmochemical reactions in a near-surface layer etc. Impact of gas-discharge plasma on the surface of substance is actively applied. The plasma impact on the processed surface can be various: bombing of a surface of substance by the fast charged particles; radiation by the electromagnetic radiation of a various spectral band, for example ultra-violet radiation; heating of material due to Joule heat at course of electric current through surface material, including induction currents in case of high frequency discharges; chemical impact on the processed surface with the substances which are formed during course of plasmochemical reactions in gas-discharge plasma, etc.

Various ways of the organization of the discharge can be applied to implementation of plasma impact on the surface of material. The simplest way is when the surface of one of electrodes, for example, of the cathode, is processed. By such method it is possible to make, for example, cleaning of a surface of the cathode of oxides or other pollution. The disadvantage of this way is its limitation on available values of parameters. It is possible to use only near electrode layers of gas-discharge plasma. Besides rather often there is an intensive thermal emission in the near electrode layers that also limits opportunities of application, for example, for coating.

Besides the near electrode areas of discharge it is possible to use for impact on surfaces, for example, the area of the positive column of a glow discharge. However this area in case of normal, diffusion burning of discharge, especially with the low pressure, occupies the free space in the



discharge camera therefore to organize the plasma influence on processed surface is rather complicated because putting the proceeded material into the plasma space will strongly change the plasma parameters. This way of influence is suitable to process fabrics, nonwoven fabrics and other high porous dielectric materials. But in this case there is a complexity for the organization of a gas flow which is used for the gas mixture cooling and updating, and for the stabilizing of discharge. The cross flow (blow-in) of gas can be used for offset of the discharge area closer to the processed surface as well, for example, in plasmatrons.

It is possible to use the creeping discharge to put discharge area directly near the processed surface, but pulse and unstable character of this discharge makes its usage inconvenient for processing of surfaces.

2. B. Timerkaev and co-workers have considered in recent works [1,2] a way of pressing of the plasma gas-discharge channel to the surface of fuel oil by means of magnetic field. It has been investigated for plasmochemical processing of heavy hydrocarbonic raw materials. Pressing of plasma was carried out under the influence of Lorentz force. It is known that electric current in gases is caused by drift of electrons and ions. Since oppositely charged particles in electric field move in opposite directions, Lorentz force for all of them will be directed in the same direction. Selecting the corresponding directions of electric and magnetic fields it is possible to achieve the discharge channel inclination towards the surface of liquid hydrocarbonic raw materials.

In works [1,2] they have performed an estimated calculation of influence of electric and magnetic fields on the movement of electrons and ions in plasma of the glow discharge near the surface of liquid hydrocarbon raw materials for pressure of 10 Tor, temperature 500 K and induction of magnetic field 0,1 T. According to the results of calculations the free path length for electrons has been obtained about 0,074 mm, the average speed of an electron on free path length (i.e. drift speed in the direction of electric field) has been obtained equal $0,16 \cdot 10^6$ m/s, and the radius of the Larmor movement has been obtained about 1,5 microns. Therefore at such magnetic field range the electron will drift in the direction, perpendicular as to electric, and to magnetic fields. At the same time at such values of magnetic field the Larmor radius for ions is about 1 mm. Thus magnetic field cannot strongly influence the ions movement on the distance of ions free path length. Consequently electrons will participate in the complicated drift movement in the direction, perpendicular to the directions of both electric and magnetic field. And plasma ions will drift towards the electrons.

The experimental setup described in works [1,2], together with system of the organization of several mutually perpendicular magnetic fields provides a possibility of management of a inclination of the plasma channel from its conditional axis. It can be used for processing of surfaces of irregular shape, concentrating plasma area near various sites of a surface during necessary time. In this way it is possible to process, for example, internal surfaces of dielectric tubes. In this case when this technique of the plasma channel inclination management is used for tubes processing it is easy to organize a longitudinal gas flow.

Gas discharge plasma tends to various types of instability and pulsations. It is a serious problem for implementation of surface technological processes. Certainly it produces additional difficulties when the magnetic field is used to manage the gas discharge plasma channel position for the surfaces processing. It is recommended to use a computer based automated control for both electrical discharge parameters and magnetic field distribution of the technology experimental setup to enhance the efficiency, quality and stability of the plasma influence on the surfaces. The method of stability increase of the gas discharge with the use of computer based automated system is described in [3].

References

- [1] Timerkaev B A, Sofronitskiy A O, Andreeva A A 2015 The glow discharge creeping along the surface and its applications. ISSN 2078-6255. Vestnik of A.N. Tupolev KSTU (Kazan: Kazan National Research Technical University Press) vol 3 pp 5-9
- [2] Timerkaev B A, Sofronitskiy A O Andreeva A A 2016 Carbon nanotubes formation in the

- decomposition of heavy hydrocarbons creeping along the surface of the glow discharge. Journal of Physics: Conference Series 669 012062 4 pages
- [3] Asadullin T Ya, Galeev I G, Timerkayev B A 2016 Way of stability increase of the glow discharge. Journal of Physics: Conference Series 669 012062 3 pages